Dynamical effects of filtering structures on the mitigation of lake eutrophication

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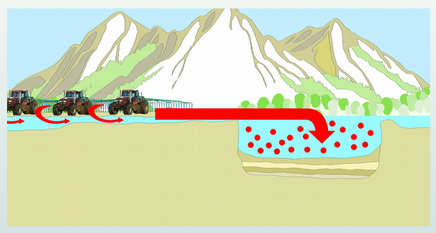
Introduction

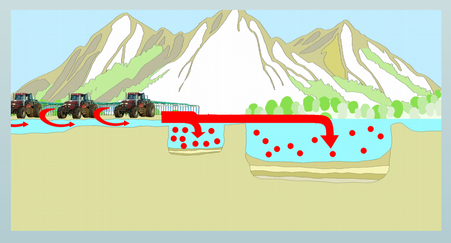
Oligotrophic lake

Eutrophic lake

Mitigation of lake eutrophication currently lies in the development of infrastructures upstream from lakes, that limit nutrient inputs, such as wetlands or sedimentation ponds. Because of their filter effect on the water passing through them, we call such structures "filtering structures". Here we examine the effects of several filtering structures on the phosphorus dynamics in a downstream lake. We adapt a dynamical model of the phosphorus quantity in a lake to study three kinds of structure according to their effect on the phosphorus: a buffer effect, a fixed trapping effect, and a varying trapping effect. These models enable us to understand the filtering structure effects on a downstream lake: we show the inertia effects of a structure with a buffer effect, and we study the cleaning of a filtering structure as a way to control phosphorus levels, and so maintain a lake in an oligotrophic state.



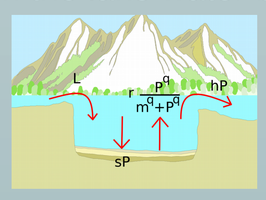
Without filtering structure



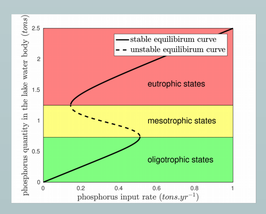
With a filtering structure

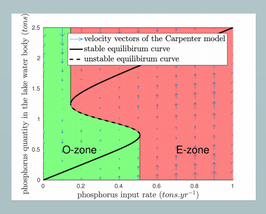
Methods

I) A dynamical Model of the Phosphorus quantity in the lake water body (*Carpenter 1999*)



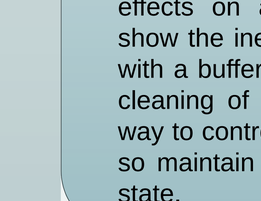
$$\frac{dP(t)}{dt} = L(t) - hP(t) - sP(t) + r\frac{P(t)^q}{m^q + P(t)^q}$$



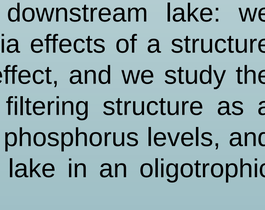


II) Three filtering structures

B-structure

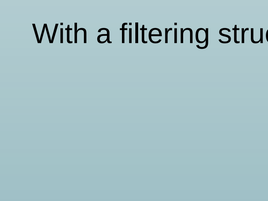


A buffer effect :



$$\frac{dP_B(t)}{dt} = L(t) - h_B P_B(t)$$

FT-structure

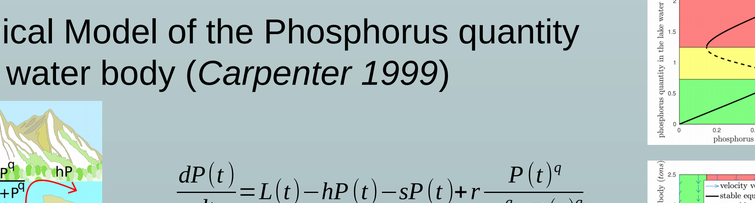


A fixed trapping effect :

$$h_{FT} P_{FT}^{eq} = \frac{h_{FT}}{s_{FT} + h_{FT}} L < L$$

$$\frac{dP_{FT}(t)}{dt} = L(t) - h_{FT} P(t) - s_{FT} P(t)$$

VT-structure



A varying trapping effect : $\frac{dP_{VT}(t)}{dt} = L(t) - (s_{VT}(t) + h_{VT}(t))\, P_{VT}(t)$

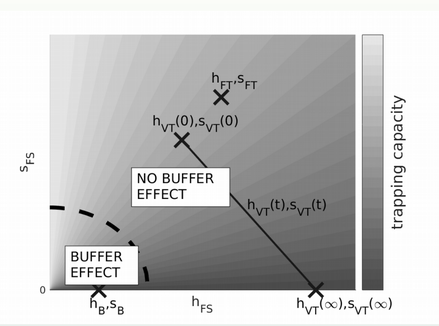
with

for $t = 0 : h_{VT}(0) = h_i$ and $s_{VT}(0) = s_i$

for $t = \infty : h_{VT}(\infty) = h_{max}$ and $s_{VT}(\infty) = 0$

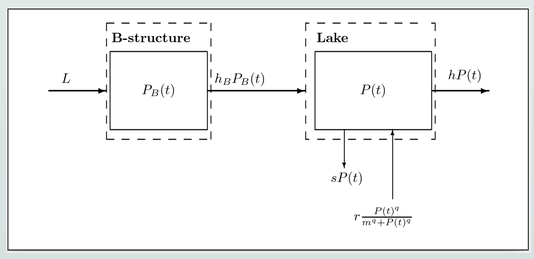
III) Conclusion

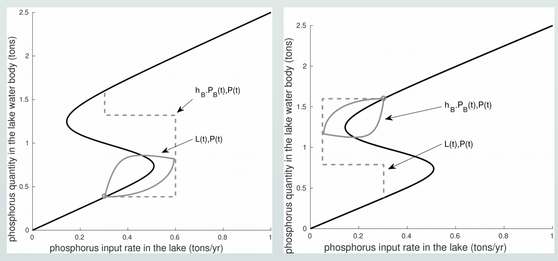
The filter effect of a filtering structure depends on its parameter values.



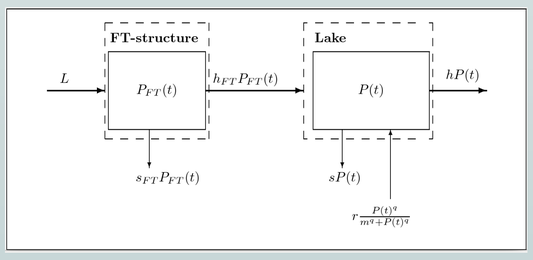
Results

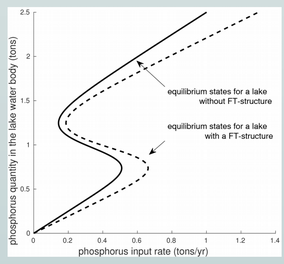
I) Effect of a B-structure on a downstream lake



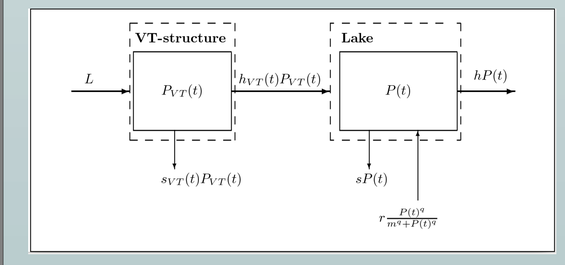


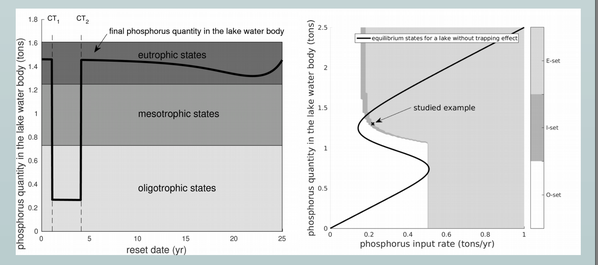
II) Effect of a FT-structure on a downstream lake





III) Effect of a VT-structure on a downstream lake





Conclusions

The B-structure increases the downstream lake inertia.

The FT-structure decreases the input phosphorus rate in the downstream lake.

The VT-structure allows to control the input phosphorus rate in the downstream lake.

We thank the Région Auvergne, France, for its financial support. This work was supported by a contrat Plan Etat Région from the Région Auvergne, France: CPER 2015-2020 -- ConnecSens.

Bibliography

Carpenter, S. R., Ludwig, D., & Brock, W. A. (1999). Management of eutrophication for lakes subject to potentially irreversible change. Ecological applications, 9(3), 751-771.